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Astronuclear Laboratory

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This is descriptive material on the tests presently planned for NERVA post-operative examination. This information is presented on a preliminary basis only in order to give guides to the Phase II design now beginning.

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Attachment

FORM 3506E

DISCLAIMER

PROPOSED TESTING TO BE PERFORMED IN THE POST-OPERATIVE CELLS OF THE E-MAD BUILDING FOR NRX-A

I. INTRODUCTION

The post-operative examinations required for development of a reliable, light weight, and high performance NERVA reactor will be quite extensive. Naturally, the examination work load will be heavy during initial phases of the program. It is probable that this work load will remain high during the later stages of the program as well. This is because the emphasis on weight reduction and performance improvement will dictate detail changes in the reactor all through the program. These changes must, of course, be verified by test and examination.

II. PRE-TESTING

In order to attain maximum utilization of the information obtained during the post-operative tests, it will be necessary to evaluate prior to the test, many of the same components examined during the post-operative tests.

It is proposed that the following evaluations should be accomplished during a pre-test examination of the core and the documentation shipped to the post-operative cells at the E-MAD facility.

1. Weights of components
2. Dimensions of components
3. Radiography
4. Ultrasonic testing
5. Flow Testing
6. Borescopic Inspection
7. Visual Inspection

In addition, on each batch or grouping of components fabricated, the following

destructive tests should be performed.

1. Hardness Testing
2. Tensile and/or Bend Testing
3. Stress Rupture Testing
4. Fatigue Testing
5. Thermal Conductivity Testing
6. Thermal Expansion Testing
7. Wear Testing
8. Corrosion Studies
9. Impact Testing
10. Metallography
    a) Structure
    b) Porosity

It will also be necessary that the preliminary data be properly documented and that each cluster, fuel element, tie rod, etc. be properly identified so that the markings can be read before and after the test. In the same manner, it will be necessary that post-operative examinations be properly documented thus enabling the data evaluation to be accomplished in other areas or locations than the post-operative cells.

III. CORE DISASSEMBLY HOT CELL

The main core disassembly will be accomplished in the Core Disassembly Hot Cell and the fuel cluster and/or the fuel elements will be started through the post-operative cells for examination. In addition, it should be noted that the larger components such as the control drum mechanisms, shields, reflectors and core plate will be sectioned in the Hot Machine Shop and then examined in the post-operative cells using similar techniques to those used on small components.

IV. POST-OPERATIVE CELL TESTS

A. Visual Inspection

Each individual fuel element cluster will be cross-checked for its serial number

and core location and then its exterior surfaces inspected for imperfections. In addition, all large components, i.e., control drums, graphite barrel, reflector segments, etc., will undergo a visual inspection and a sampling of small components, i.e., graphite tiles, springs, etc., will be visually inspected. If any component indicates any particular effects of interest it will be set aside for later more detailed inspection.

In its simplest form, visual inspection involves thorough examination, perhaps with the aid of binoculars or a magnifying glass. At least two commercial methods have been developed which improve the reliability of visual inspection. In the Zyglo method (registered trade name of the Magnaflux Corp.), the part to be inspected is dipped into, sprayed, or brushed with a water-soluble penetrant dye. The excess penetrant is allowed to drain, and after a time interval to allow for complete penetration, the part is gently washed in a water spray and then dried by an air blast. Upon dusting with an absorbent powder, the fluorescent dye solution is drawn from discontinuities. The part is then exposed to ultraviolet light and the locations of the flaws are shown. Dy-Chek (registered trade name of Northrup Aircraft, Inc.) involves four basic steps:

1. The surface of the specimen is cleaned.
2. The penetrant is applied by dipping, spraying, or brushing.
3. After an interval to allow for penetration, the excess dye is removed with a cleaning solution.
4. A white developing solution is added.

As the developer dries, it is colored red by the dye which has penetrated into cracks and discontinuities.

Visual methods using only a magnifying glass or binoculars are the slowest, most tedious, and the least reliable method for detection of flaws. Dyes and

fluorescent materials make the recognition of cracks and other defects easier, are equally applicable to ferrous or nonferrous metals as well as large or small objects, do not require expensive installations of equipment, and are portable.

B. Weighing

This examination is necessary to determine any change in the weight of the component due to oxidation, hydrogenation, irradiation, corrosion, etc. that has occurred since the pre-test evaluation. It is expected that a sensitive balance will be used which projects the weight reading against one wall of the cell, thereby enabling the weight to be easily observed. If this unit cannot be obtained, a magnifying device will be mounted in front of the unit to enable the unit to be easily read.

It is proposed that one-sixth of the clusters and any defective clusters be weighed. In addition, the component parts after disassembly of the one-sixth of the core and the defective units will also be weighed (fuel elements will be weighed with an accuracy 0.1 gram). In addition, all major components, i.e., outer reflector, graphite barrel, control drums, etcs. will be weighed and a selected sample of minor parts such as springs, nuts, and bolts, will also be weighed.

C. Dimensional Checks

This examination will determine any dimensional changes due to the firing. This will be accomplished by comparison of the pre-test and post-operative dimensions. The post-operative cell will be equipped whereby either micrometer or vernier readings of the dimension may be obtained for all core components.

It is proposed that one-sixth of the clusters and any defective clusters will be checked dimensionally. In addition, the same components, after disassembly of the one-sixth of the core and the defective clusters, will also be dimensionally

checked. In addition, all major components, i.e., outer reflector, graphite barrel, control drums, etc., and a selected sample of springs, nuts and bolts will be dimensionally checked.

D. Periscopic Equipment

This examination will be used as a supplement to the visual inspection phase of the post-operative studies, in order to investigate more fully the surface imperfections of the core components and to evaluate more accurately the effect of the test. The cell will be equipped with periscope sleeves just above the cell windows and a periscope will be permanently installed. Periscopes are usually equipped with objectives that permit viewing at two diameters and ten diameters.

It is expected that all defective components uncovered during the visual inspection will be examined using the periscope.

E. Microscopic Photography

Periscopes in many cases in addition to being equipped with magnification capabilities may be equipped with camera attachments. This type of instrument permits photography in order to retain for off-site inspection a picture of the surface defect.

Another useful piece of equipment to be used in addition to the periscope is a stereo-microscope. The stereo-microscope not only magnifies the object and has a camera attachment, but also shows the relative depth of shallow holes, cracks and other flaws.

It is expected that all defective components uncovered during the visual inspection and verified as defective by periscopic examination would be photographed for later analysis.

F. Borescopic Examination

The flow holes of various core components will be borescopically examined to detect any changes that may have taken place during firing. The borescope will have an integral light source and, if possible, a camera attachment. A sleeve through the cell wall will be required and the borescope will be permanently attached to the cell. It is proposed that the hydrogen flow holes of approximately twenty-five elements will be examined and photographed by this method.

G. Radiography

Radiography will be utilized for determination of any subsurface imperfections that may have been caused by the test.

Radiography is a non-destructive method of internal examination in which materials are exposed to a beam of x-rays. In the x-ray tube, a stream of electrons is accelerated by a high voltage drop and directed at a target. When the target is struck by the high velocity electrons, it emits some electromagnetic radiations which have suitably short wave lengths for radiographic examination. The variations in the intensity of the transmitted radiation are recorded on sensitized film.

The darker regions on the radiograph correspond to thinner sections, voids, or non-metallic impurities since these regions transmit more radiation. In the case of a single radiograph for two or more different materials, the intensity of transmitted radiation decreases with increasing values of the individual absorption coefficients (μ) if the materials are of the same thickness. As the atomic number increases, μ increases. The ability of radiography to detect void spaces is limited by the scattering of x-rays and by lack of parallelism in the radiation emitted from the source. Therefore, for radiography to detect successfully the presence of a void, the void should represent at least three percent of the

thickness of the metal, measured in the direction of the radiation. The x-ray equipment usually lacks portability.

The variations of the x-ray exposure of the film will be interpreted concerning subsurface imperfections and by comparison to the pre-test x-ray, the test effects can be determined. It is expected that one-sixth of the core will be examined using radiography. In addition, all major components, i.e., outer reflector, graphite barrel, controls drums, etc., and a selected sampling of springs, nuts, bolts, will be checked using radiography.

H. Ultrasonic Inspection

Ultrasonic test instruments utilize high frequency sound waves produced by applying an alternating current voltage of suitable frequency to a quartz crystal. Quartz is a piezoelectrical substance, therefore, a change in dimensions of the crystal, as produced by an applied force, will result in generation of a voltage. Two kinds of instruments are used in this method of detection on internal flaws. One type relies upon reflection of a sound wave from the defect, while the other records a decrease in the value of the sound beam transmitted as a result of interference with the flaw.

In the reflecting type instrument, the sound input is converted to a visual signal on a cathode-ray oscilloscope. A reflection from the far surface of the part being examined also shows up on the oscilloscope, but at the far end of the sweep. A defect between the surface where the sound beam enters and where it is reflected shows up as a pip between the input signal and the reflected signal. Since the velocity of the sound is constant in a given metal and since it travels in a straight line through the metal, the distance from the input signal to the pip and from the pip to reflected signal locates the discontinuity. The size and character of the pip indicates the size and character of the defect.

In instruments which rely upon variations caused by defects in the path of a transmitted signal, separate crystals are used for sending and receiving the sound beam. A defect in the path of the beam reflects and absorbs some of the incident sound energy so that the intensity of the transmission is reduced. This type of instrument can be used to examine much thinner specimens than reflection-type devices. However, it is limited to shapes whose thickness between sending and receiving crystals is uniform. The maximum permissible thickness is five inches whereas with reflected beams, good results are obtained in pieces up to thirty feet long.

Reflection instruments have greater flexibility and are more portable. This method provides a thorough means of internal examination, but it is fairly slow and expensive. It will be especially useful on components, such as fuel elements, where the gamma emission may cloud the film in the radiography or in cases where the defect runs in the same direction as the guided x-ray path.

It is expected that a total of one-sixth of the core will be ultrasonically inspected to detect any subsurface imperfections caused by the firing.

I. Flow Testing

Approximately one-sixth of the fuel clusters will be tested in order to determine the roughness and friction factors of the flow holes using an instrumented air, nitrogen or helium flow loop. If any of the clusters show that there is a change in the flow characteristics from the initial pre-test flow then the individual components of that cluster will be analysed.

There may be a need to flow test the orifices after high power operation to determine if any changes occurred due to radiation, or the thermal gradients. This test will follow an inspection in order to determine the breakage rate of the fuel element orifices.

J. Gamma Scanning

There are basically two types of gamma scanning presently in use for analysing the KIWI cores and they are gross and incremental.

1. Gross Gamma Scanning

Gross gamma scanning utilizes an ionization chamber in which the fuel element is inserted. The current flow in the chamber is measured and recorded. This then indicates the total activation or power output when compared to the remaining elements of the core.

2. Incremental Gamma Scanning

Incremental gamma scanning uses a collimator between the component and the NaI crystal and views the gamma activity at many points along the length of the element. The points are then plotted and the power distribution shape for each element is determined. If the fuel elements of entire core are gamma scanned incrementally then the power distribution shape of the entire core can be determined. However, since there is symmetry in a hexagonal array core, in order to obtain a complete power distribution shape it will only be necessary to gamma scan incrementally one-sixth of the core.

LASL presently has automatic units to do both types of gamma scanning and similar units are visualized for the E-MAD Building.

K. Machining

This operation encompasses the machining of tensile bars, impact bars, etc., from the various reactor components. The necessary equipment includes a cut-off machine, a lathe, and a milling machine, all of which will be operated remotely from outside the cell. The lathe and milling machine may be used in conjunction with templates to provide for ease of operation as well as accuracy of results.

L. Sectioning

This operation encompasses the sectioning, polishing, and grinding in preparation for metallography studies The sectioning will be accomplished on at least one sample of each component of the core that functions properly. If a component has a malfunction, 3 or 4 sectionings may be required to evaluate the difficulty.

M. Hardness Testing

The testing of the hardness of the material will be accomplished in order to compare the pre-test and post-mortem readings to determine any change in the component characteristics.

Indentation hardness or resistance to localized penetration is widely used industrially as a measure of hardness, and indirectly as an indicator of other desired properties in a manufactured product. The indentation tests through imperical relationships of hardness to such properties as tensile strength, fatigue strength and impact strength, pieces likely to be deficient in these latter properties may be detected and rejected.

Brinell hardness is determined by forcing a hardened sphere under a known load into the surface of a material and measuring the diameter of the indentation left after the test The Brinell hardness number is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimeters.

In the Rockwell method of hardness testing, the depth of penetration of an indentor under certain aritrary conditions of test is determined. A variety of combinations of indentor and major load are possible.

As compared with the Brinell test, the Rockwell method makes a smaller indentation, and is therefore considered non-destructive for most applications; it may be used on thinner material, and is much more rapid since hardness numbers are read directly and need not be calculated.

The Rockwell Superficial Tests are used on very thin materials or on clad. The most economic superficial tests are R 30 N for hard materials and R 30 T for soft materials. American Chain & Cable Co. now offers a machine capable of performing both regular and superficial testing. This instrument is called a Twin-Tester.

Microhardness

The principal uses of microhardness testers are measuring the hardness of constituent particles in alloys, thin surface-hardened layers, foils, single grains, interfaces and diffusion zones, etc. Both the Knoop and Diamond Pyramid tests are the ultimate in accuracy as far as hardness testing is concerned. Reliable information indicates the availability of a commercial remoted Tukon microhardness tester.

It is proposed that one-twelfth of the core will be examined to determine the hardness of the material. In addition, all major components, i.e, outer reflector, inner reflector, control drums, etc., and a selected sample of springs, nuts and bolts will be checked to determine the hardness of the material.

N. Tensile Testing

The tensile strength of the components will be determined for comparison to the pre-test material strength. A change in the tensile strength or mode of facture is indicative of a change in the material during the reactor test.

The tensile strength is obtained by forces attempting to pull the test specimen apart and is calculated by dividing the maximum load during the test by the original cross-sectional area. A measure of the ductility of the material after fracture is given by the percent elongation and also by the reduction of area.

The percent elongation after fracture is determined by dividing the change in the original gage length by the original gage length, this ratio multiplied by 100 percent. The original gage length should always be stated in reporting percent elongation values. The percent reduction in area after fracture is the ratio of the change in the original area determined at the smallest cross-section to the original area of cross-section, this ratio multiplied by 100.

The type of fracture in tension gives some indication of the quality of the material, but this is considerably affected by the testing temperature, speed of testing, the shape and size of the specimen, and other conditions. Contradiction is greatest in tough and ductile materials and least in brittle materials. In general, fractures are either of the shear or of the separation (loss of cohesion) types. Separation failures occur in brittle materials, such as certain cast irons. Combinations of both shear and separation failures are common on round specimens of ductile metal.

The stress concentration factor, effect of a notch in the specimen, can be determined experimentally by fracture tests on brittle materials. Stress concentration is not important for ductile metals under static loading since any plastic flow will eliminate it, in whole or in part, through a redistribution of stress. Brittle materials are sensitive to stress concentration even under static loading. Stress concentration is important for most

materials subjected to fluctuating or oscillating stresses.

It is proposed that one-twelfth of the core will be examined to determine the tensile strength of the material. In addition, all major components, i.e., outer reflector, inner reflector, control drums, etc, and a selected sample of springs, nuts and bolts will be checked to determine the tensile strength of the material.

O. Impact Testing

Most impact machines are designed so that they can be used for both Charpy and Izod impact tests. A typical machine consists essentially of a heavy, free-swinging pendulum, a rigid frame, and a vise or anvil for holding the specimen. Specimens for the Izod test are held in a vise at one end and loaded at the other, making this type of test a cantilever beam test. In the Charpy test, the specimen is supported at its ends on an anvil and is loaded as a simple beam.

A pendulum of known weight is raised to a specific height and allowed to fall, striking the pendulum. The energy absorbed by the specimen is the difference between the energy remaining after the blow and the energy input at the time of the impact. After the specimen is broken, the energy remaining in the pendulum carries it upward, moving a pointer along an indicator scale which reads directly the foot-pounds of energy absorbed by breaking the specimen. The impact behavior of a given material is affected greatly by the temperature of the member.

The test results of notched specimens are directly applicable only to parts in service which have the same shape notch as the test specimen and are subjected to the same temperature and speed of loading and for which size corrections can be made. Therefore, impact tests of notched specimens,

particularly from Charpy and Izod tests, are rarely if ever applied directly to design problems. The results of these tests are quite useful when correlated with known service behavior of the same material. Although correlations are far from perfect, the results of Charpy tests give a better indication of metals to failure under triaxial stresses and low temperatures than do static tensile tests. The Charpy and Izod tests yield comparative indications of notch sensitivity, transition temperature, toughness, and ductility. They do not produce information on shock loading at high velocities, since much higher velocities are needed for studies of this type.

The appearance of the fracture resulting from an impact test should not be overlooked. A silky appearance indicates a ductile fracture in which shear has occurred and a granular appearance indicates a brittle, cleavage-type fracture.

At the present time, it is proposed that one-sixth of core be impact tested.

P. Radiochemistry

The purpose of this test is to determine the fission distribution in selected fuel elements from the core following the power transients. The test will provide an absolute calibration for the subsequent power mapping of the reactor core.

The most critical unknown in power mapping a reactor core is the proportionality constant between radiation intensity and number of fissions. Radiochemical analysis offers an excellent means of determining the absolute number of fissions.

Approximately one-twelfth of all fuel elements will be selected for radiochemical analysis. From these, 30 elements will be cut into small segments, each to be analysed separately. Certain fission products are highly retained in the fuel elements. Quantitative analysis will determine the amounts of these highly retained fission products present in each fuel element and each element segment. Then knowing the fission yield of these fission products, one can determine the total fissions which occurred in the fuel element during operation. The proportionality constant between radiation intensity and number of fissions can be determined from this data and previous radiation level measurements.

Since ranges of fission products are extremely short, analysing the individual element segments will determine the axial fission distribution as well as the radial.

In addition, a detailed radiochemistry will be performed on one sample from each material in the core to determine any nuclides formed during the test. This is necessary due to the fact that the formation of the nuclides may adversely affect the physical characteristics of the material.

Q. Metallography

Metallography is the science dealing with the constitution and structure of metals and alloys as revealed by the unaided eye or by such tools as low-powered magnification, optical microscope, electron microscope, or x-ray diffraction techniques.

After sectioning, the sample is mounted in a plastic resin to provide ease of handling. Then the sample is ground to a 600 grit finish and later polished to obtain a scratch-free surface. The polished sample is viewed using a metallograph and any pores, cracks, or flaws are photographed at

a suitable magnification. The sample is then etched to reveal the structure and again examined using a metallograph. Photomicrographs may again be obtained at this time, depending upon the decision of the metallographer and/or the project engineer. Metallography also involves the shooting of photomacrographs.

X-ray diffraction is largely used to determine the submicroscopic structure of materials. The regular external form of crystals suggests that within them the elementary atoms, molecules, or ions are arranged regularly. The criterion for classifying these regularly arranged crystals into distinct systems is based on the angles between the axes and the length of the axes. On this basis, the following six crystal systems have been recognized: cubic, tetragonal, orthorhombic, monoclinic, triclinic, and hexagonal.

At the present time, it is expected that representative portions of one-sixth of the core plus defective parts will be examined utilizing a remote operated metallography; however, we do not plan to use any x-ray diffraction examination.

R. Density

The density of the different core components will be obtained in order to determine any change in the density of the material due to the test. Density is of particular interest for certain materials where transmutation causes a swelling of the material and for fuel components where center-melting may have taken place.

There are two common methods of determining density in use today. In the first method, the piece is weighed and dimensioned very carefully. The density is then obtained by dividing the weight by the volume. A serious

drawback to this method is the necessity for regular shapes.

The other method involves no dimensions, but relies entirely upon weights. The sample is initially weighed in air and later weighed in a suitable liquid, such as wetted water or carbon tetrachloride. Irregular shapes present no problem using this method, but the density of materials which are adversely affected by aqueous solutions cannot be obtained in this manner.

S. Corrosion Studies

Determination of the effects of various conditions to which the components might be exposed will be determined using corrosion studies, i.e., exposure of the materials under controlled pressure, temperature, time and various gaseous atmospheres. This test may be more properly called environment testing.

T. Fatigue Testing

Fatigue testing will be accomplished on components that undergo a constant stress cycle during the test.

Fatigue refers to the failure of materials under the action of repeated stresses. It is responsible for a large proportion of the failures occurring in machine parts. In fatigue testing, a specimen is subjected to periodically varying stresses by means of mechanical or magnetic devices. The most common loading is alternate tension and compression of equal numerical values obtained by rotating a smooth cylindrical specimen while under a bending load. A series of fatigue tests are made on a number of specimens of the material at different stress levels. The stress endured is then plotted against the number of cycles sustained. By choosing lower and lower

stresses, a value may be found which will not produce failure, regardless of the number of applied cycles. This stress value is called the endurance limit. Surface defects, such as roughness or scratches, and notches or shoulders, all reduce the fatigue strength of a part.

It is expected that about 20 percent of the springs will be examined using this test. The possible reasons for failure are 1) possible transmutation of an impurity, 2) the hardening effect of the radiation, and 3) the embrittling effect of radiation.

U. Stress Rupture Testing

The stress rupture test measures the creep of a material. In metals, creep is a plastic deformation caused by slip occurring along crystallographic directions in individual crystals, together with some flow of the grain boundary material. After complete release of the load, a small fraction of this plastic deformation is recovered with time. Most of the flow is non-recoverable for metals. Experience has shown that, for the design of equipment subjected to sustained loading at elevated temperatures, little reliance can be placed on the usual short-time tensile properties of metals at those temperatures. Under the application of a constant load, it has been found that materials, both metallic and non-metallic, show a gradual flow or creep even for stresses below the proportional limit at elevated temperatures. The deformation which can be permitted in the satisfactory operation of most high-temperature equipment is limited.

The test is conducted by applying a dead weight to one end of a level system, the other end being attached to the specimen surrounded by a furnace and thereby held at constant temperature. The nominal stress is then plotted versus the time for fracture.

Structural changes may occur during a creep test thus altering the metallurgical condition of the metal. In some cases, premature rupture appears at a low fracture strain in a normally ductile metal indicating that the material had become embrittled. This is a very insidious condition and difficult to predict; however, the stress-rupture test is well adapted to study this effect.

The difference in the modes of fracture between the pre-firing and the post-operative testing are compared for determining embrittlement or weakening of the material. It is expected that specimens will be machined from one-twelfth of the fuel elements and tie rods and at least three samples from each of the major components such as the steel barrel, outer reflector, inner reflector, etc.

V. Thermal Expansion Testing

The thermal expansion plus the coefficient of linear expansion of the irradiated core materials may be determined by this test. It is possible that the coefficient may change due to irradiation.

Initially, a given sample of the material will be accurately measured. Then the sample will be heated and the temperature as well as the dimensions will be determined. The coefficient of linear expansion will then be obtained by calculations.

W. Thermal Conductivity Test

A simplified statement of the test is that a heat source is placed at one end of a specimen and the temperature at the other end is measured. The difference of the thermal conductivity between the pre-test and the post-operative results are compared to determine the effects of the core

test. Various units have different thermal conductivity requirements.

The fuel elements require high thermal conductivity, whereas the pyrolytic tiles, in one direction, require very low thermal conductivity.

It is expected that at least one sample of each pertinent core component will be tested.

X. Coefficient of Friction Determination

A simplification of the test is the determination of the effect of friction when two surfaces rub together. This will be useful because surfaces of various materials will rub together during reactor operation due to stresses and actions allowed by the design. It will also be necessary to compare the pre-test and post-operative results since changes are suspected in the surface conditions of some materials.

It is expected that at least one sample from each material in the core will be examined.

Y. Wear Testing

Wear may be caused by pounding, abrasion, or galling. It is not felt that wear caused by pounding will be a consideration in the firing, but wear caused by abrasion or galling could be very important.

Abrasion occurs when stresses which exceed both the elastic limit and the rupture strength are developed in the surface of the metal. The nature of abrasion involves a sliding action between the part being worn and the substance causing the wear. Sometimes the temperature at the interface

becomes high enough to affect adversely the properties of the metal. When this happens, abrasive wear ceases to be a room-temperature phenomena and the high-temperature hardness of the metal should be considered. No technique is available for telling what surface temperatures are developed in some cases of abrasive wear, so there is difficulty in classifying these as either high or low temperature failures.

When the clean surfaces of two metals are forced together under sufficient pressure, a weld may be formed. Upon pulling the two pieces of metal apart, the stronger metal tends to pull fragments of the weaker metals from the latter's surface. This is known as galling or seizing and sometimes occurs between journals and bearings.

V. Disposition of Unfinished Tests

Any post-operative examination on a core component that cannot be completed in the post-operative cells will be completed at other locations. This may be necessitated due to limits on space allotted and the large number of examinations necessary.